

SPECIFICATION

TITLE OF THE INVENTION

OPTICAL INFORMATION RECORDING APPARATUS FOR
STABLE RECORDING

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BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an apparatus and a method for recording information in a recording medium such as an optical disk by applying a laser beam to an optical recording medium.

2. Description of Prior Art

An optical information recording medium such as an optical disk has been recently developed and marketed as an external memory of a computer and a medium for recording images and sounds. Optical disks that are already practically used and in which data can be recorded include organic-dye-based, phase-change-type, and magneto-optic disks in which data is recorded by applying a laser beam to a recording film.

Pulse width modulation (hereinafter referred to as PWM) is known for recording data in an optical disk at a high density. The PWM technology performs modulation so that edges at the leading and trailing ends of record marks correspond to 1 of a digital signal. It is favorable in order to record data at a high density because more bits can be assigned in a record mark of the same length than the pulse position modulation technology for performing modulation so that the position of a record mark corresponds to 1 of a digital signal.

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In the PWM technique, it is necessary to form a record mark without distortion, that is, form the leading and trailing ends of the record mark in the same quality because the width of record mark has information. Especially, when a long mark is formed in a phase-change-type optical disk, the width in the radial direction of a record mark increases toward the latter-half portion due to the thermal storage effect of a recording film, that is, the record mark is distorted like a tear drop. In order to solve the problem, a recording method is proposed for forming one record mark by applying a plurality of short pulse strings (e.g. Japanese patent laid-open Publication No. 185628/1990).

A general optical disk has a spiral track or concentric information tracks on the disk surface, and it records or reproduces information by applying a laser beam along the information track. In order to manage recording data easily, the information track is divided into sectors and addresses are given to the sectors.

The data format of an optical disk in which data can be recorded can be roughly classified into two types. One of them has a sector format in which address sections and data sections are separated from each other. Magneto-optic disk and DVD-RAM standardized by ISO/IEC 10089 and the like belong to this type. Because the address sections are completely separated, address reproduction and data recording can be performed by time sharing without interfering each other even on recording. Moreover, a buffer area referred to as a gap area is generally provided at a boundary between a address section and a data section. Therefore, a recording apparatus can perform laser power control in any sector even when data is currently recorded, by using the gap area.

The other type has a sector format in which address sections and data sections are not separated from each other. CD-R, CR-RW, DVD-R, DVD-RW and the like belong to this type. Because there is no separated address section, it is possible to continuously record data, and it is possible to increase the recording density (format efficiency). However, it is necessary to reproduce addresses while recording data. Thus, it is necessary to control laser power under data recording.

A recording apparatus for CD-R controls to optimize recording laser power with a process referred to as optimum power control (OPC) when information is recorded. OPC is performed by recording and reproducing predetermined data in a power calibration area (hereafter referred to as PCA) in an optical disk. For example, test recording is performed to the PCA by changing laser power in the unit of sync frame and by reproducing the area to which test recording is performed. Then, laser power with which the best recording state is obtained is selected, and it is used as recording power for recording user data (refer to Orange Book of optical-disk recordable standards).

Moreover, there is another method referred to as running optimum power control (R-OPC) for controlling the recording power in accordance with the quantity of light reflected from an optical disk when user data is recorded. In R-OPC, the light quantity on forming recording marks to record user data in the above-mentioned OPC is compared with that obtained in the OPC, and the laser power is corrected in real time in accordance with the comparison result. As a mark part for obtaining the light quantity, 11T mark is used (e.g. Japanese Patent laid open Publication No. 40548/1998). An 11T mark has mark length equivalent to the longest mark length of Eight-to-Fourteen-Modulation (EFM)

code used for the CD standards, and the synchronization code of a sync frame has 11T mark and 11T space. Therefore, it has a mark length which appears at least once in a sync frame.

As mentioned above, in the continuous recording format such as CD-R/RW or DVD-R/RW, light quantity of reflected light from a disk is changed according to modulation of a laser beam on data recording. Therefore, it is difficult to stably reproduce an address signal. Moreover, because there is not a period for controlling the laser power while recording user data, it is necessary to control the laser power in accordance with the light quantity of light emitted by a laser or light quantity of reflected light from a disk while recording data. For example, in order to sample-and-hold a high power part of a laser beam on recording, it is necessary to generate a sampling pulse corresponding to the timing of the record pulse signal for modulating the laser.

However, in correspondence to recent application of consumer appliances from audio recording to image recording, or in order to meet recent demands for high speed operation speed of peripheral units of a computer, the recording rate of an optical disk recording apparatus becomes higher. As the recording rate is increased, it becomes impossible to ignore influences on stable sampling of a detection signal of transmission characteristics (propagation delay and settling) in a detection system for light quantity of emitted laser beam or of reflected light, fluctuations of power-supply voltage and temperature of the system and the like.

This is because when the recording rate is enhanced, the absolute time for the same mark length is shortened and thereby, it is not easy to secure the time required to surely sample-and-hold the laser power. Moreover, the

time axis of a monitoring signal for the light quantity of emitted laser beam or reflected one to be sampled-and-held depends on the transmission characteristics (propagation delay and settling) in a detection system or fluctuations of power-supply voltage and temperature of the system. Therefore, a problem occurs that the time margin for stable sampling-and-holding runs becomes short.

Moreover, as mentioned above, in the case of CD-R/RW, 11T which is the longest mark length appears at least once in a sync frame. The sync code of DVD-R/RW includes 14T only once, and 14T becomes a mark or a space depending on the series of modulated data just before the 14T mark. Therefore, a 14T mark does not always appear once in a sync mark. Further, the longest mark length of 8-16 modulation code used for DVD-R/RW is equal to 11T, similarly to the case of the EFM modulation code. However, the appearance probability of the 8-16 modulation code is very low, and it is not assured that the code appears at equal intervals. Therefore, particularly in the case of DVD-R/RW, there are problems that the DVD-R/RW has a recording rate higher than that of CD-R/RW and that it is difficult to obtain a mark length (or space length) capable of stably performing sampling-and-holding at a necessary time interval.

SUMMARY OF THE INVENTION

An object of the present invention is to provide an apparatus and a method which can set optimum laser power while data are recorded to an optical disk or the like.

Another object of the present invention is to provide an apparatus

and a method which can reproduces address signals and servo signals stably and reliably while data are recorded to an optical disk or the like.

In one aspect of the invention, an optical information recording and reproducing apparatus records information by emitting a laser beam modulated according to recording data to a recording medium. The apparatus comprises a laser light source which emits a laser beam to a recording medium, a recording pulse generator which generates recording pulse signals to modulate optical intensity of the laser light source according to recording data, a laser driver which drives the laser light source according to the recording pulse signals, a photodetector which detects the laser beam emitted by the laser light source, a sampler which samples an output signal of the photodetector, and a sampling timing generator which generates a sampling timing to instruct sampling to the sampler. The sampling timing generator generates a sampling timing delayed at least by a response time of a propagation path including the laser driver, the laser light source and the photodetector. Preferably, the sampling timing generator generates a sampling timing for a record mark (such as a space portion) having a length longer than a sum of a settling time of a signal propagating the propagation path and a necessary acquisition time and a necessary aperture time of said sampler.

Similarly, in a different optical information recording and reproducing apparatus, a photodetector detects the laser beam emitted by the laser light source and reflected by a recording medium. The sampling timing generator generates a sampling timing delayed at least by a response time of a propagation path including the laser driver, the laser light source and the photodetector.

In another aspect of the invention, an optical information recording and reproducing apparatus which records information by emitting a laser beam modulated according to recording data to a recording medium having pits formed as address information for managing data position. The apparatus comprises a laser light source which emits a laser beam to a track in a recording medium for recording data, a recording pulse generator which generates recording pulse signals to modulate optical intensity of the laser light source according to the recording data on recording, a laser driver which drives the laser light source according to the recording pulse signals, a photodetector which detects the laser beam emitted by the laser light source and reflected by the recording medium, a first binarizer which binarizes an output signal of the photodetector with a first slicing level, a second binarizer which binarizes an output signal of the photodetector with a second slicing level, a selector which selects one of a first output signal of the first binarizer and a second output signal of the second binarizer, a selection signal generator which generates a selection signal to instruct the selector which of the first and second output signals, and a reproducer which reproduces address information by using an output signal of the selector. The selection signal generator generates a timing of the selection signal according to response time of a propagation path including the laser driver, the laser light source, the photodetector, and the first and second binarizers. Preferably, the sampling timing generator generates a sampling timing for a record mark (such as a space portion) having a length longer than a sum of a settling time of a signal propagating the propagation path and a necessary acquisition time and a necessary aperture time of the sampler. Preferably, the sampling timing generator changes a sampling timing according

to a type of the recording medium.

In a further aspect of the invention, in a method of optical information recording by emitting a laser beam by a laser light source to a recording medium, the laser beam having intensity modulated according to recording data. The method comprises the steps of applying a recording pulse to the laser light source to emit a pulse light beam according to the recording pulse, detecting light quantity of the emitted pulse light beam, and sample-and-holding the detected light quantity according to a sampling pulse to detect optical intensity of the laser beam. The timing of the sampling pulse is delayed at least by response time of a recording pulse in a propagation path from application of the recording pulse until just before sample-and-holding it, and the timing is generated for a recording mark having a length longer than a sum of a necessary acquisition time and a necessary aperture time for sampling.

Similarly, in a different optical information recording and reproducing method, the laser beam emitted by the laser light source and reflected by a recording medium is detected. Then, a sampling timing is delayed at least by a response time of a propagation path including the laser driver, the laser light source and the photodetector.

An advantage of the present invention is that the sampling timing for detecting laser beam can always be optimized.

Another advantage of the present invention is that reliability of the apparatus and the method of optical information recording can be improved largely.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects and features of the present invention will become clear from the following description taken in conjunction with the preferred embodiments thereof with reference to the accompanying drawings, and in which:

5 Fig. 1 is a block diagram of the configuration of the optical information recording apparatus of a first embodiment of the invention;

 Fig. 2 is a timing chart for explaining internal operations of the optical information recording apparatus;

10 Fig. 3 is a block diagram of an internal configuration of the sampling pulse generator; and

 Fig. 4 is a block diagram of an apparatus configuration for measuring the response time of a propagation path;

 Fig. 5 is a diagram for explaining the response time measurement of a propagation path by a response time measurement unit;

15 Fig. 6 is a block diagram of an internal configuration of the response time measurement unit;

 Fig. 7 is a block diagram of another internal configuration of the response time measurement unit;

20 Fig. 8 is a block diagram of a pulse timing setting unit and its peripheral configuration;

 Fig. 9 is a block diagram of the configuration of an optical information recording apparatus of the second embodiment of the invention;

25 Figs. 10A, 10B and 10C are diagrams on the relationship between sensitivity, light quantity of reflection light, and optimum monitoring position of the light quantity of a recording film of a recording medium, wherein Fig. 10A is

a graph of recording multi-pulse, and Figs. 10B and 10C are graphs of light quantity of reflection light for high sensitivity recording film and for low sensitivity recording film;

Fig. 11 is a block diagram of the configuration of an optical information recording apparatus of a third embodiment of the invention; and

Fig. 12 is a block diagram of the configuration of an optical information recording apparatus of still a fourth embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings, wherein like reference characters designate like or corresponding parts throughout the several views, Fig. 1 shows a configuration of an optical information recording apparatus of a first embodiment of the invention. In Fig. 1, for recording or reproduction of data, a laser beam emitted from a laser diode 102 is converged by an optical system 103 to irradiate a beam spot onto the recording face of an optical recording medium 101.

When data is recorded, a data modulator 106 adds error correction redundant bits to user data to be recorded according to the necessity and outputs data 1a modulated to a code series to be recorded in the optical recording medium 101. For example, DVD-R uses 8-16 modulation code as a recording code series, and mark lengths and space lengths to be formed are restricted to 3T to 11T and 14T wherein 1T denotes a recording channel clock period. Therefore, by relating high level of the modulated data 1a to a mark of a recording signal and low level thereof to a space of the recording signal, the modulated data 1a becomes a digital signal whose high and low levels are

restricted to the widths of 3T to 11T and 14T.

A recording pulse generator 105 generates a recording pulse signal 1b obtained by processing the timing of the modulated data 1a sent from the data modulator 106 according to necessity and outputs the signal 1b to a laser driver 104. The waveform of the recording pulse signal 1b is based on the multi-pulse recording waveform mentioned above in order to avoid, for example, a recording mark from becoming a tear drop shape due to thermal storage in a recording film. Moreover, the recording pulse generator 105 outputs a sampling pulse reference timing 1i serving as the criterion of a sampling pulse output signal to a sampling pulse generator 110, as will be described later.

The laser driver 104 supplies a laser driving current 1c so that the laser diode 102 emits light beam with the recording power in accordance with the timing of the recording pulse signal 1b. Further, the laser driver 104 generates the current 1c so that the laser diode 102 emits light beam with the reproducing power for reproducing data.

A photodetector (or photoelectric converter) 107 converts light intensity to electrical signal, and it is mounted in the optical system 103. That is, the photodetector 107 detects the light 107 emitted from the laser diode 102 and converts the emitted light to a current having an amplitude corresponding to the intensity of the emitted light.

The output current 1d of the photodetector 107 is sent to a signal processor 108. In the signal processor 108, at least I/V conversion for converting current to voltage signal is performed. Thereafter, gain conversion is performed for changing voltage amplitudes according to necessity, and filtering is also performed for extracting only a specified frequency component. Then, a

monitoring voltage signal 1e subjected to the above signal processing is outputted to a sampler 109.

The sampler 109 samples-and-holds the monitoring-voltage signal 1e sent by the signal processor 108 at the timing of a sampling pulse 1f sent from a sampling pulse generator 110. A signal 1g sampled-and-held by the sampler 109 is supplied to a laser power controller 111.

The laser power controller 111 sets recording power 1h of the laser driver 104 for the emitted light in accordance with the signal 1g sampled-and-held by the sampler 109 after propagating the laser diode 102, the photodetector 107, the signal processor 108 and the sampler 109. For example, the laser power controller 111 adjusts the setting value 1h of recording-power so that the recording power for forming a recording mark in the optical recording medium 101 has an amplitude level predetermined by the sampling-and-holding output signal 1g.

A pulse timing setting unit 112 sets setting value 1j of sampling pulse for the sampling pulse generator 110 and setting value 1l of the recording pulse for the recording pulse generator 105.

Fig. 2 is a timing chart of timings in the parts shown in Fig 1. This example shows recording waveforms for 9T mark, 4T space, and 3T mark.

The recording pulse signal 1b has a multi-pulse waveform shown in Fig. 2 for the modulated data 1a. The laser-driving current 1c is generated delayed by T_{d1} than the recording pulse signal 1b. In this case, T_{d1} is assumed as the circuit propagation delay time of the laser driver 104.

The laser diode 102 emits light in accordance with the laser driving current 1c, and the output current 1d of the photodetector 107 for

detecting the emitted light is obtained as shown in Fig. 2. The propagation time from the laser emission to the output of the photoelectric conversion of the emitted light is represented as Td2.

5 The monitoring voltage signal 1e after subjected to I/V conversion, gain conversion, and filtering by the signal processor 108 has a waveform shown in Fig. 2. The delay time due to signal processing is represented as Td3.

10 The sampler 109 samples-and-holds the monitoring voltage signal 1e received from the signal processor 108 at the timing of the sampling pulse 1f (or it samples the signal 1e in the low level period in Fig. 2). However, in order to accurately monitor the recording power for forming a recording mark, it is necessary to sample the monitoring voltage signal 1e surely while the recording power is emitted.

The timing of the sampling pulse 1f depends on the following factors,

- 15 (1) propagation delay time,
(2) settling time,
and
(3) data recording frequency.

20 In the apparatus of this embodiment, the propagation delay time in the above factor (1) shows a sum of delay times in the propagation path of the emitted laser beam on recording, the propagation path consisting of the laser driver 104, the laser diode 102, the photodetection 107, and signal processor 108. The sum amounts to $Td1 + Td2 + Td3$.

25 The propagation delay time represents a period from the start time when the recording pulse generator 105 outputs leading end of the first wave in

the recording pulse 1b to the end time when a rising waveform corresponding to the first wave in the recording pulse 1b appears in the monitoring voltage signal 1e received from the signal processor 108. Therefore, in order to sample-and-hold the amplitude of a portion corresponding to the recording power, it is necessary to begin to output a sampling pulse after delaying the recording pulse at least by the time corresponding to the propagation delay time ($Td1 + Td2 + Td3$).

The settling time in the above factor (2) can be paraphrased as the time until waveform deterioration caused by the components such as the laser driver in the propagation path converges. This depends on the frequency characteristics of the components. When the sampling start timing is decided only by the propagation delay time, a deteriorated waveform is sampled so that it is impossible to detect an accurate power value. Therefore, it is preferable to delay a recording pulse by the time obtained by a sum of the settling time and the propagation delay time and to start to output the sampling pulse thereafter. In order to estimate the settling time, for example, it is preferable to calculate an average of a root of a sum of squares of the settling times for the components.

The data recording frequency in the above factor (3) relates to the time length of a recording mark. If the time obtained by subtracting the settling time from the application time of the recording power of each recording mark is shorter than the sum of the acquisition time and the aperture time of the sampler 109, it is impossible to detect an accurate power value. Therefore, a recording mark length to which a sampling pulse should be output must be longer at least than the sum of the settling time of the propagation path and the necessary acquisition time and the necessary aperture time of the sampler 109.

To sum up, it is preferable (a) to make the sampling pulse start timing delayed at least by the sum of the propagation delay time and the settling time of the propagation path from the leading end of the first waveform of a recording pulse, (b) to make the width of a sampling pulse larger than the necessary acquisition time of the sampler 109, and (c) to make a recording mark length at least longer than the sum of the settling time of the propagation path and the necessary acquisition time and the necessary aperture time of the sampler 109.

The sampling pulse start timing t_x and the shortest recording mark length n to which a sampling pulse should be output can be shown by the following formulae,

$$t_x > T_d + T_s, \quad (1)$$

and

$$n > (T_s + T_w + T_a) \cdot f, \quad (2)$$

wherein T_d denotes propagation delay time of the propagation path, T_s denotes settling time of the path, f ($= 1/T$) denotes the recording frequency of the path, T_w denotes the sampling pulse width of the path, and T_a denotes the aperture time of the sampler 109.

As mentioned above, the sampling timing generator 110 generates the timing t_x to start sampling delayed from the leading end of the first wave of a recording pulse at least by a sum of the propagation delay time T_d of the propagation path (that is, the laser driver 104, the laser diode 102, the photodetector 107 and the signal processor 108) and the settling time T_s of the sampler 109. In a technique therefor, the response time had been measured for each component or a combination of the components by sending an input

signal and by receiving an output signal, and T_d and T_s are set to appropriate fixed values. The propagation time and the settling time can also be measured on the entire propagation path by a device as shown in Fig. 4 as will be explained later. Thus, the sampling pulse start timing t_x can be set based on the measurement. It is also possible to measure the response characteristics on some of the components in the propagation path beforehand and to measure the other components by the measurement under data recording. Thus, the sampling pulse start timing t_x can be determined based on the previously determined characteristics and the newly measured characteristics under data recording. In either way, the sampling pulse start timing t_x can be changed so that it always has an appropriate value.

Next, a configuration of the sampling pulse generator 110 for generating the timing of a sampling pulse is explained with reference to Fig. 3 showing an internal configuration thereof. In Fig. 3, numerical references 1101a and 1101b denote a D-flip-flops. A recording clock signal 11a having a $1T$ cycle is supplied to each clock terminal. It is preferable to have the same phase of the recording clock signal 11a as that of a signal used by the recording pulse generator 105.

The D-flip-flops 1101a constitute a $(k-1)$ stages shift register and receives the sampling pulse reference timing $1i$ at an input, and a selector 1102 selects one of the sampling pulse reference timing $1i$ and outputs Q of D-flip-flops at $(k-1)$ stages in accordance with a selection signal 11c. The selected output 11b is further inputted to another D-flip-flop 1101b, and an inverse clock 11e (phase shift of 180°) of the recording clock signal 11a is connected to the clock terminal of the flip-flop 1101b. A selector 1103 selects either the output

11b or Q output of the D-flip-flop 1101b selected in accordance with a selection signal 11d to output it as a sampling pulse 1f.

According to the above configuration, it is possible to easily provide the sampling pulse generator which changes the sampling pulse in a range between $0T$ and $(k-0.5)*T$ for the sampling pulse reference timing 1i by using the flip-flops.

The sampling pulse reference timing signal 1i has $3T$ width synchronous with the first wave of the recording pulse 1b for a recording mark length to which the sampling pulse should be output. It is needless to say that the sampling pulse reference timing 1i is not restricted to $3T$ width. It may be decided in the relationship on the necessary acquisition time, and the width thereof can be changed.

Further, the start position of the sampling pulse reference timing 1i is not restricted to the synchronization with the first wave of the recording pulse 1b. It may be decided with reference to the minimum value of (propagation delay time + settling time) of the propagation path. The number of stages k of the D-flip-flops may be estimated in accordance with (maximum value - minimum value) of (propagation delay time + settling time) of the propagation path.

Though the unit of timing is set to $0.5T$, the unit is not restricted to $0.5T$. It is also possible to set the unit to $1T$ or $0.25T$. In the case of $1T$ unit, it is needless to say that the D-flip-flop 1101b at the final stage and the selector 1103 are unnecessary. In the case of $0.25T$, it is possible to operate the D-flip-flops at the final stage at a cycle $1/4$ of the cycle of the recording clock signal 11a in accordance with a clock signal whose phase is set to that of the

recording clock signal 11a.

Furthermore, it is preferable to decide sampling pulse timing basically in accordance with the Expressions (1) and (2). For example, when the propagation delay time of the propagation path is 10 nanoseconds, the settling time thereof is 50 nanoseconds, and the recording frequency thereof is 30 MHz (1T = 33 nanoseconds), the sampling pulse start timing tx is as follows by using Expression (1).

$$tx > 100 + 50 = 150 \text{ ns.}$$

Because 1T is equal to 33 nanoseconds,

$$tx > (150 \div 33)T \cong 4.55T.$$

Therefore, it is preferable to select a position of five or more stages in terms of the number of stages of the D-flip-flops.

Furthermore, when the aperture time of the sampler 109 is 10 nanoseconds, the minimum recording-mark length n to which a sampling pulse should be output is as follows,

$$n > (50 \text{ ns} + 3T + 10 \text{ ns}) * f,$$

by using Expression (2). Because

$$f = 1/T = 30 \text{ MHz,}$$

$$n > 4.8.$$

Therefore, it is preferable to output a sampling pulse to a recording mark of 5T or more.

Next, it is explained how to obtain the propagation delay time and settling time of the propagation path, by referring to Figs. 6 and 12.

Fig. 4 is a block diagram of a configuration for obtaining the propagation delay time and the settling time of the propagation path by using a

test signal. In Fig. 4, components provided with the same symbols as those in Fig. 1, that is, an optical recording medium 101, a laser diode 102, an optical system 103, laser driver 104, and signal processor 108 are the same as those described for Fig. 1. Therefore, the description of functions thereof are omitted here. Moreover, Fig. 5 is a timing chart for explaining operations of the components in Fig. 4.

A test pulse generator 602 outputs a test pulse signal 6a to the laser driver 104 in the test mode. Because the test pulse signal 6a is outputted to measure the response characteristic of the propagation path, it is preferable to use a rectangular wave having a width larger enough than that of a recording pulse signal in normal operation so that the response characteristic can be stably measured.

The laser driver 104 receives the test pulse signal 6a and applies driving current 6b to the laser diode 102 so that the laser 102 emits light beam with the power equal to a predetermined recording power.

The laser beam is emitted by the laser diode 102 with the applied driving current 6b and detected by the photodetector 107 similarly to the case of normal recording. Then, a current signal 6c having an amplitude corresponding to the light quantity of the emitted light is outputted.

The signal processor 108 outputs an output signal 6d obtained by signal processing such as I/V conversion on the input current signal to the response time measurement unit 601, 6c similarly to the case of normal recording. A timing signal 6e indicating the start of measurement of response time is separately inputted to the response time measurement unit 601 by the test pulse generator 602. It is possible that the timing signal 6e is the same as

the test pulse signal 6a.

Fig. 6 shows an internal configuration of the response time measurement unit 601. This device comprises a comparator 701 for comparing the input 6d supplied from the signal processor 108 with a predetermined voltage level and a counter 702 for measuring the delay time of an output signal of the comparator 701 and the timing signal 6e supplied from the test pulse generator 602.

In the test mode, when the leading end (change point from low level to high level) of the test pulse signal 6a is applied, the output signal 6d of the signal processor rises in accordance with the response characteristic of the propagation path after a predetermined time elapses. When the output signal 6d of the signal processor becomes higher than a preset comparison-voltage level, the comparator 701 outputs high level. It is necessary to adjust the comparison voltage level so that the portion of a deteriorated waveform under settling is kept lower than high level and the portion where the waveform is completely settled surely becomes high level.

The counter 702 measures the time from the leading end of the timing signal 6e to the leading end of the output signal of the comparator 701, by counting the time with fixed-frequency clock signals. It is preferable that the cycle of the clock signal is equal to or longer than the timing change unit of sampling pulse.

As described above, it is possible to measure the response time of the propagation path with a simple configuration by using the comparator and the counter. It is preferable to decide the value of the sampling pulse timing setting 1j of the sampling pulse generator 110 described above on Fig. 1 under

normal recording, based on the response time measured in the test mode.

Fig. 7 shows another configuration of the response time measurement unit 601. This comprises an analog-to-digital (A/D) converter 801 which converts the analog waveform of an output 1d of the signal processor 108 to digital signal, a memory device 802 for storing the digital data after the analog-to-digital conversion, and a detector 803 for detecting the leading end of waveform from the stored digital signal to measure the time relationship with the timing signal 6e showing the start position of the test pulse signal 6a.

The digital signal corresponding to the output signal 6d of the signal processor 108 converted to digital signal by the A/D converter 801 is stored in the memory device 802 synchronously with the timing signal 6e indicating the start of measurement of response time. It is preferable that the acquisition interval of digital-signal sampling with the memory device 802 is equal to or longer than the timing change unit of sampling pulse. The memory device 802 may comprise of a first-in first-out memory or a random access memory such as an SRAM or DRAM. The detector 803 reads the value of a digital signal sample stored in the memory device 802 and detects what sample in the portion of the leading end. It is preferable to detect the sample of the portion where a waveform is completely settled by excluding the portion of a deteriorated waveform under settling. It is possible to determine the response time of the propagation path from the position of the detected sample.

As described above, in the configuration shown in Fig. 7, it is possible to detect the position of leading end by confirming the transient value of the digital signal sample stored in the memory device 802. Therefore, even if the amplitude level of the output signal 1d received by the signal processor 108

changes or the waveform under settling overshoots, it is possible to prevent the position of leading end from being undetected or erroneously detected. Therefore, it is possible to more stably measure the response time of the propagation path compared to the configuration of the comparator and the counter shown in Fig. 6.

The configuration shown in Fig. 7 is slightly more complex than the configuration shown in Fig. 6. However, if the A/D converter 801 and the memory device 802 can be shared with other functional blocks, the cost will not increase. For example, in an optical information recording/reproducing apparatus, when a part or the whole of reproduction signal processor comprises a digital circuit, it is preferable to share the component because a high-speed A/D converter is generally used. Moreover, because a buffer memory is often used for an optical disk drive in order to temporarily store recording data or reproduction data, it is preferable to share the buffer memory. Furthermore, when the detector 803 uses a digital signal processor (DSP) or a central processing unit (CPU) provided for another function, it is possible to realize the function through software processing by using the DSP or CPU.

In the above description, the response time of the output signal 6d of the signal processor 108 to the test pulse signal 6a is measured at the leading end of the output signal 6d. However, it is also possible to measure the response time at the trailing end when necessary or use the measurement at the leading end and the measurement at the trailing end together.

Moreover, in the test mode, it is unnecessary to emit a laser beam to the optical recording medium 101 because only the response time of the propagation path is measured.

Furthermore, the response time measurement unit 601 and the test pulse generator 602 may be set or not in the optical information recording apparatus shown in Fig. 1. When setting the components 601 and 602 in the apparatus, it is possible to measure the response characteristic of the propagation path by setting the test mode while the apparatus is actually operated. Therefore, even if response characteristics of the propagation path are changed due to change of ambient temperatures or fluctuations of power-supply voltage while the apparatus operates, it is always possible to keep the timing of sampling pulse properly correspondingly to the change or fluctuations.

When the response time measurement unit 601 and the test pulse generator 602 are not mounted in the apparatus, it is necessary that the recording pulse 1b or an input of the laser driver 104 can be controlled from the external before the apparatus is shipped and that the monitoring voltage signal 1e supplied from the signal processor 108 can be monitored from the external. When these conditions are satisfied, it is possible to individually adjust the value of the sampling pulse timing setting 1j by measuring the response characteristic of the propagation path before shipment of the apparatus. Therefore, when if the response characteristic is different among the apparatuses, it is possible to properly keep the timing of sampling pulse by adjustment for each apparatus. Because the response time measurement unit 601 or the test pulse generator 602 is not equipped, the cost of the apparatus can be reduced.

Even when the response time measurement unit 601 and the test pulse generator 602 are not set in the apparatus, if means for monitoring the power supply voltage and the ambient temperature are added newly, it is always possible to properly keep the timing of sampling pulse correspondingly

to the fluctuation of power-supply voltage or ambient temperature.

An example for realizing the above-described method is described below by referring to Fig. 8 which shows an internal and peripheral configuration of the pulse timing setting unit 112.

5 A pulse timing setting unit 112 includes a first table 903 on setting value of sampling pulse and a second table 904 on setting value of recording pulse. The first table 903 is used for deciding the value of the sampling pulse setting 1j by using the recording frequency, response characteristic of the propagation path (or response characteristic measured beforehand at room temperature and at normal voltage), result of power-supply-voltage monitoring, and result of temperature monitoring as parameters. The power-supply-voltage monitoring result uses an output of the power-supply-voltage monitoring device 901. The temperature monitoring result uses an output of the temperature monitoring device 902.

10 The second table 904 decides the recording pulse setting 11 in accordance with a predetermined recording strategy and decides a mark length to which a sampling pulse should be output by using recording frequency, propagation-path response characteristic, result of power-supply-voltage monitoring, and result of temperature monitoring as parameters.

15 The two tables 903 and 904 may comprise a read only memory (ROM) which stores a set value for parameter inputs or a computer unit for obtaining a set value by applying parameter inputs to the above Expressions (1) or (2), or with use of a software processing. For example, when factors of power-supply-voltage fluctuation and ambient-temperature fluctuation are taken into account, Expressions (1) and (2) are rewritten as follows;

$$t_x > (T_d + T_s) \cdot (1 - p \cdot v) \cdot (1 + q \cdot t), \quad (5)$$

and

$$n > \{T_s \cdot (1 - p \cdot v) \cdot ((1 + q \cdot t) + T_w + T_a) \cdot f, \quad (6)$$

wherein p denotes power-supply fluctuation coefficient, d q denotes
 5 temperature fluctuation coefficient, v denotes difference between the reference
 power-supply voltage and the result of monitoring a power-supply voltage, and t
 denotes difference between the room temperature and the result of monitoring
 temperature. In general, because the propagation delay time and the settling
 time are shortened as the power-supply voltage rises, the power-supply
 10 fluctuation coefficient is set to have a negative value ($-p$). Moreover, in general,
 because the propagation delay time and the settling time are increased as
 ambient temperature rises, the temperature fluctuation coefficient is set to a
 positive value ($+q$).

The above expressions are formulated by assuming that the
 15 propagation delay time T_d and the settling time T_s are affected by the power-
 supply-voltage fluctuation and the ambient temperature fluctuation. However,
 T_w and T_a may be multiplied by a coefficient similarly by assuming that the
 acquisition time and the aperture time are also affected by fluctuations thereof.
 Moreover, the propagation time and the settling time may be formulated by
 20 using different values for the power-supply fluctuation coefficient and
 temperature fluctuation coefficient.

By setting the pulse timing setting unit in an optical information
 recording apparatus, it is always possible to properly keep the timing of
 sampling pulse correspondingly to the fluctuations of power-supply voltage or
 25 ambient temperature without using the response time measurement unit 601

and the test pulse generator 602.

The test pulse generator 602 may be used together with the recording pulse generator 105. That is, the recording pulse generator 105 can be operated so as to generate a recording pulse 1b in accordance with the modulated data 1a in the normal recording mode and to generate a test pulse signal 6a to measure the response characteristic of the propagation path in the test mode. Thus, the increase in the cost of setting the test pulse generator 602 to the apparatus is almost diminished.

Two types of configurations of the response-time measurement unit 601 for measuring the response time of the propagation path are described above. However, it is needless to say that a configuration of the response time measurement unit 601 is not restricted to the above two types.

In this embodiment, a method for detecting the power (recording power) for forming a recording mark is described. However, this embodiment is not restricted to the formation of recording marks. For example, it is possible to use this technique for detecting the power of a portion (space portion) at which no recording mark is formed.

A recording method is proposed for a rewritable phase-change medium applied to a DVD-RAM or the like, which changes three or more levels of laser power on recording such as the peak power for forming a recording mark by making the recording film amorphous, the bias power for forming a space portion by crystallizing the recording film, and the bottom power for forming a recording mark by a multi-pulse. It is possible that the method and configuration described for this embodiment can be applied to detection of any power level in addition to the above three power levels.

In the first embodiment, as described by referring to a plurality of drawings, it is shown that light quantity of emitted laser beam can be accurately detected always at an optimum timing by changing the timing of sampling pulse for the sampler in accordance with the response time of the propagation path from the generation of a recording pulse signal to the sampler through signal processing such as the photodetector and the I/V conversion. Thus, it is always possible to optimally control the laser power and to improve the recording reliability of the optical information recording apparatus.

In the first embodiment, the concept of the present invention is applied to the detection of light quantity of emitted laser beam and the control of laser power. In a next embodiment, however, the concept of the present invention is applied to detection of light quantity of laser beam emitted to and reflected from an optical recording medium.

Fig. 9 is a block diagram of an optical information recording apparatus of a second embodiment of the present invention. In Fig. 9, components having the same reference numerals as those in Fig. 1, that is, an optical recording medium 101, a laser diode 102, a laser driver 104, a recording pulse generator 105, and a data modulator 106 are the same as those described above with reference to Fig. 1. Therefore, the explanation thereon is omitted here.

In Fig. 9, an optical system 201 includes a photodetector 202 for detecting the light quantity of the laser beam emitted to and reflected from the recording face of the optical recording medium 101. The photodetector 202 outputs a current signal 2d having an amplitude corresponding to the intensity of reflected light.

A signal-processor 203 outputs a monitoring-voltage signal 2e obtained by using the signal processing such as I/V conversion to an output current 2d of the photoconductor 202 to the sampler 204. The sampler 204 samples-and-holds the monitoring voltage signal 2e at the timing of a sampling pulse 2f supplied from a sampling pulse generator 206. The output 2g of the result of the sampling-and-holding is supplied to a laser power controller 205.

The laser power controller 205 sets recording power setting value 2h of the laser driver 104 in accordance with the output 2g sampled by sampler 204. For example, the laser power controller 205 adjusts the recording power setting value 2h so that the output 2g corresponding to the monitoring result of the light quantity of light beam reflected from the optical recording medium 101 has a certain amplitude level.

By monitoring the light quantity of light beam reflected from an optical recording medium under the recording, it is possible to understand the state for forming a recording mark. For example, the laser power controller 205 can be applied to form a recording mark through thermal decomposition or substrate deformation of a recording film made of an organic-dye-based material such as DVD-R by irradiating the laser beam to a recording medium having the recording film. A method of controlling recording power in accordance with the reflected-light quantity from an optical recording medium under the recording is known as the R-OPC described above.

The timing of the sampling pulse 2f by the sampling pulse generator 206 is decided in accordance with the following factors,

(1) propagation delay time,

(2) settling time,

- (3) data recording frequency,
and
(4) type of optical recording medium.

In this embodiment, the propagation delay time in the above factor
5 (1) denotes a sum of delay times in the propagation path of the light beam
emitted by the laser diode to and reflected from an optical recording medium,
that is, the path formed between the laser driver 104, the laser diode 102, the
optical recording medium 101, the photodetector 202, and the signal processor
203.

10 The settling time in the above factor (2) denotes the time until
waveform deterioration caused by each component in the propagation path
converges similarly to the description for the first embodiment. It depends on
the frequency characteristic of each factor.

15 The data recording frequency in the above factor (3) relates with
the time length of a recording mark. As described for the first embodiment, a
recording mark length to which a sampling pulse should be outputted must be
longer at least than the sum of the settling time of the propagation path and the
necessary acquisition time and necessary aperture time of the sampler 204.

20 The type of optical recording medium in the above factor (4) can
also be the type of material of a recording film. Because it is an object to get a
recording-mark forming state by monitoring a reflected-light quantity, it is
necessary for control of optimum power to monitor the light quantity of the
reflected light beam at a position where change in the reflected-light quantity is
maximized. However, the change point of the light quantity depends on the
25 sensitivity of a recording film.

Figs. 10A - 10C illustrate the relationship between sensitivity of recording film, light quantity and optimum monitoring position. When high laser power due to a recording multi-pulse shown in Fig. 10A is applied, formation of a recording mark is quickly progressed when a recording film has high sensitivity. Therefore, as shown in Fig. 10B, the light quantity of the reflection light is changed quickly. On the other hand, when a recording film has low sensitivity, the light quantity is changed slowly as shown in Fig. 10C because it takes a longer time to form a recording mark. The optimum monitoring position of the light quantity differs as illustrated in Figs. 10B and 10C. The time from the start of the first wave of a recording pulse to the optimum monitoring position is defined as delay time of forming recording marks.

In short, the start timing of sampling pulse is determined in accordance with the propagation delay time and the settling time of the propagation path and the recording-mark formation delay time after rise of the first wave in a recording pulse. The width of the sampling pulse is set to a value longer than the necessary acquisition time of the sampler 204. Further, a recording-mark length to which a sampling pulse should be output is decided by considering the sum of the settling time of the propagation path and the necessary acquisition time and the necessary aperture time of the sampler 204 with the delay time of recording mark formation.

A sampling pulse start timing t_y and a minimum recording-mark length to which a sampling pulse should be outputted can be shown by the following formulae,

$$t_y > \{T_d + F(T_s + T_m)\}, \quad (3)$$

and

$$m > \{F(T_s + T_m) + T_w + T_a\} * f, \quad (4)$$

wherein T_d denotes propagation delay time of propagation path, T_s denotes propagation path settling time, T_m denotes delay time of recording-mark-formation, $f (= 1/T)$ denotes recording frequency, T_w denotes sampling pulse width, and T_a denotes aperture time of the sampler 109. In this case, $F(T_s + T_m)$ denotes a function to define a root of a sum of squares of T_s and T_m , $(T_s^2 + T_m^2)^{1/2}$. The settling time T_s and the recording mark formation delay time T_m are additional factors different from the propagation delay time T_d . Because T_s and T_m are events independent of each other, they can be estimated by the above-mentioned addition of squares.

It is preferable to decide the timing of a sampling pulse by basically using Expressions (3) and (4). It is preferable to generate the sampling pulse $2f$ by the sampling pulse generator 206 in accordance with the process and the configuration of the embodiment shown in Fig. 3 and the like.

Moreover, the response time (the propagation delay time and the settling time) of the propagation path is the same as that explained above in the first embodiment, except that detection of light quantity is performed on the light beam reflected from an optical recording medium. Therefore, the explanation on the response time is omitted here. Because it is necessary to detect the light quantity of the reflected light beam, it is needless to say that it is necessary to apply a laser beam to the optical recording medium 101 similarly to the case of normal recording also in the test mode for measuring the response time.

As mentioned above on the second embodiment with reference to the drawings, it is always possible to accurately detect the light quantity of emitted laser beam at an optimum timing by changing the timing of a sampling

pulse to the sampler in accordance with the response time of the propagation path from the recording pulse signal to the sampler through the laser diode, the optical recording medium, the photodetector, and the signal processing such as I/V conversion.

5 Moreover, because the time up to formation of a recording mark depends on the type of optical recording medium, it is shown to change timings of a sampling pulse in accordance with the delay time of the formation of the recording mark. Thus, it is always possible to optimally control the laser power and to improve the recording reliability of an optical information recording apparatus.

10 A method for detecting the power (recording power) to form a recording mark is described above for this embodiment, and a method for detecting the power is not restricted to this method. For example, it is possible to use a method for detecting the power of a portion (space portion) in which no recording mark is formed.

15 Moreover, a recording method is proposed for a rewritable phase-change medium applied to a DVD-RAM and the like, which changes three or more laser power levels such as the peak power for forming a recording mark by making a recording film amorphous under the recording operation, the bias power for forming a space portion by crystallizing a recording film, and the bottom power for forming a recording mark by a multi-pulse under the recording operation. It is possible to apply the method and configuration described above on this embodiment to the detection of any one of the above three or more power levels.

20 In this embodiment, the monitoring result of the light quantity of

the light beam reflected from an optical recording medium under the recording operation is used for the control of recording laser power. However, the use of the monitoring result is not restricted to the above case. For example, it is also possible to use the monitoring result as tracking servo system detection signal (tracking error signal) in order to stabilize the laser-beam tracking under the recording operation.

Fig. 11 shows a third embodiment an optical information recording apparatus of the invention on the detection of reflected light. In Fig. 11, the components having the same reference numerals as those in Figs. 1 and 2, that is, a laser diode 102, a laser driver 104, a recording pulse generator 105, and a data modulator 106 are the same as those in Figs. 1 and 2 and therefore, the description thereon is omitted here. In the apparatus shown in Fig. 11, a laser beam emitted from the laser diode 102 is condensed by an object lens 303 mounted in an optical pickup 302 and applied to the recording face of an optical disk 301.

Though not illustrated in Fig. 11, the optical disk 301 is rotated by a spindle motor or the like, and the laser beam is controlled on tracking and on focusing so that it is guided along a guide groove (track) formed on the recording face. That is, the object lens 303 is positioned by driving an actuator 310 so that information can be recorded or reproduced.

The reflected light from the optical disk 301 enters a photodetector 305 through a prism mirror 304, and it is converted to a current signal. Though not shown, the photodetector 305 is divided into a plurality of photo-detecting sections. Then, it is possible to detect the light quantity of the light beam reflected from the optical disk 301 by each of the divided photo-detecting

sections to output a detection current from each photo-detecting section. For example, when the photodetector is divided into two sections in the tracking direction of the optical disk 301, it is possible to obtain a tracking error signal according to the known push-pull process, by obtaining the difference between outputs of the two divided sections from a signal processor 306.

The signal processor 306 performs proper signal processing such as I/V conversion and addition/subtraction of signals of the divided photo-detecting sections. A signal processed by the signal processor 306 is sampled-and-held by a sampler 307 at the timing of a sampling pulse supplied from a sampling pulse generator 309.

The timing of a sampling pulse is changeable in accordance with the setting of a pulse timing setting unit 311, and details of the changing process are previously explained for the second embodiment. That is, the timing of a sampling pulse and a space length to which the sampling pulse should be outputted may be changed in accordance with the response time of the propagation path of the reflected light. The light quantity reflected from a space portion does not fluctuate much depending on the type of a recording medium under data recording. Therefore, the timing of a sampling pulse may not be changed in accordance with the type of a recording medium in this embodiment.

According to the above-mentioned configuration, only a space portion is used for the sampling period of the tracking error signal, and a holding period is assigned to a recording mark portion to which a high power laser beam is applied according to a recording pulse. Therefore, it is possible to decrease the fluctuations of a tracking error signal under data recording due to

leak of recording pulse. Thus, the S/N ratio of tracking error signal under data recording is remarkably improved, and the stability of tracking control can be improved.

Moreover, the monitoring result of the light quantity of reflected light beam may be sampled-and-held at a variable timing of sampling pulse. Then, detection signals for clock reproduction recorded in an optical recording medium can be obtained stably under the recording. Furthermore, the monitoring result of the light quantity of reflected light beam may be binarized by using two types of binarization means having binarization slice levels different from each other and select the result in accordance with the selection signal for variable timing. Then, the detection signal for reproducing prepit address recorded in an optical recording medium can be obtained stably under recording.

Fig. 12 shows is an optical information recording apparatus of a fourth embodiment of the present invention which also uses sampling-and-holding result of the light quantity of reflected light. In Fig. 12, components provided with the same reference numerals as those in Figs. 1, 2 and 3, that is, a laser diode 102, laser driver 104, recording pulse generator 105, data modulator 106, an optical pickup 302, an object lens 303, a prism mirror 304, and a photodetector 305 are the same as those described for Figs. 1, 2, and 3. Therefore, the explanation thereon is omitted here.

Though not shown explicitly, an optical disk 400 includes information for obtaining recording clocks serving as a criterion for data recording and for determining an address for managing the position of data. The recording clocks and the information had been recorded.

The information for obtaining recording clocks uses, for example,

a wobble groove used for an optical disk format such as DVD-R, DVD-RW, or DVD-RAM. A wobble groove has a guide groove meandering at a predetermined cycle formed spirally or concentrically in an optical disk along an information track. Because the guide groove meanders in the radial direction of the optical disk, that is, a direction vertical to the beam tracking direction, it is possible to reproduce a wobble signal serving as a signal component corresponding to the meandering cycle of the wobble groove by using the tracking error signal according to the known push-pull process. By using a phase-locked loop circuit for multiplication in accordance with the wobble signal, it is possible to reproduce a clock signal having a multiplied frequency of the meandering cycle of the wobble groove and to use the clock signal as a reference clock for data recording.

Moreover, the information for obtaining the address uses, for example, a land prepit used for an optical disk format of DVD-R or DVD-RW. In general, in an optical disk, a portion of a guide groove spirally or concentrically pre-cut is referred to as groove and another portion between a groove and an adjacent groove is referred to as land. The land prepit is constituted by forming a pit at a portion of land at a predetermined interval when cutting an optical disk to store the address information.

In optical disk format such as DVD-R or DVD-RW, user data is recorded in a groove. Therefore, a beam spot of an information recording apparatus is controlled on tracking so as to follow the center of the groove. Because the land prepit is detected at a position shifted from the beam spot, it is possible to reproduce the user data by using a tracking error signal according to the known push-pull process similarly to the case of the wobble signal.

In the apparatus shown in Fig. 12, recording clocks are obtained by detecting signals for reproducing clocks recorded beforehand in the optical disk 400. Therefore, the output of the sampler 401 obtained by sampling-and-holding is inputted to a recording clock generator 402. Moreover, in order to obtain the address information of a physical position in an optical disk from the detection signal for address reproduction previously recorded in an optical disk, one of binarized signals binarized at two binarization slice levels different from each other is selected and inputted to address reproduction device 403.

In detail, a detection current 4a detected by the photodetector 305 under data recording is subjected to proper processing such as I/V conversion and filtering in a signal processor 406. Then, a reproduction signal 4b containing a signal component corresponding to land prepit information and a reproduction signal 4c containing a signal component corresponding to the meandering cycle of a wobble groove are generated and outputted.

The reproduction signal 4b is inputted to binarizers 405a and 405b. The binarizer 405a binarizes the reproduction signal 4b for lower laser power portions under data reproducing and recording, and its binarization slice level is set to a level capable of binarization and extracting land prepit information under low-laser power irradiation. On the other hand, the binarizer 405b binarizes the reproduction signal 4b for a high laser power portion under data recording, and its binarization slice level is set to a level capable of binarizing and extracting land prepit information under high laser power irradiation. That is, the binarization slice level of the binarizer 405b is set to a level higher than the binarization slice level of the binarizer 405a.

As described above, either of binarized signals 4d and 4e

obtained by the two types of the binarizers 405a and 405b is selected and outputted to the address reproduction device 403 as a land prepit binarized signal 4h. The binarized signal 4d or 4e is selected by a selector 404 in accordance with a timing signal 4g for selection supplied from a sampling pulse generator 407.

The reproduction signal 4c is inputted to the sampler 401, and the sampler 401 samples-and-holds it at the timing of a sampling pulse 4f supplied from the sampling pulse generator 407 and outputs the signal sampled-and-held to a recording clock generator 4i.

The sampling pulse generator 407 changes the timing of the sampling pulse 4f and that of the selection-timing signal 4g in accordance with the setting of a pulse timing setting unit 408. Details of the changing process are explained above for the second embodiment. That is, the start timing of the sampling pulse 4f, the change timing of the selection timing signal 4g, and the space length to which the sampling pulse 4f should be outputted may be changed in accordance with the response time of the propagation path of the reflected light of the laser beam. Further, because the light quantity at a space portion does not vary largely with the type of recording medium, it may be unnecessary to change these timings in accordance with the type of recording medium in this embodiment.

The above-described configuration makes it possible to eliminate the fluctuations of a wobble signal under data recording caused by leak of recording pulse by using only a space portion as the sampling period of the wobble signal under data recording and the recording-mark portion to which a high-power laser beam is applied due to application of the recording pulse as a

holding period. Thus, the S/N ratio of the wobble signal under data recording is improved and the jitter of a recording clock can be reduced. Thus, it is possible to improve the recording performance and the reliability.

Moreover, by preparing the two types of binarizers for a land prepit with different binarization slicing levels for a mark portion and for a space portion, and by changing the two binarized signals in accordance with the change of mark and space, it is possible to always binarize the land prepit at an optimum slicing level under data recording. Thus, it is possible to improve the read error rate of a land-prepit address under data recording and the reliability of data recording is improved.

Though not explained above in detail, a circuit for servo error may be fabricated as described in, for example, Japanese patent laid open Publication 7-3202828/1995. A circuit for detection of prepit information may be fabricated as described in, for example, Japanese patent laid open Publication 10-3202828/1998. Further, a circuit for wobble signal may be fabricated as described in, for example, Japanese patent laid open Publication 2000-113454. With reference to these publications here, they are incorporated in the ~~specification.~~

By using the configurations of the optical information recording apparatuses of the embodiments and the above-mentioned laser beam intensity detection method explained above, sampling timing of detection of laser beam emitted to a recording medium or detection of laser beam reflected from a recording medium can be changed appropriately in accordance with the propagation delay time and the settling time of the system. Then, the sampling timing of a detection signal can always be kept properly even if there are

Further, it is possible to keep laser power optimum in any case while data is recorded in a recording medium such as an optical disk, to stably reproduce servo signal, address signal, and clock signal. Thus, the reliability of the apparatus is remarkably improved.

Although the present invention has been fully described in connection with the preferred embodiments thereof with reference to the accompanying drawings, it is to be noted that various changes and modifications are apparent to those skilled in the art. Such changes and modifications are to be understood as included within the scope of the present invention as defined by the appended claims unless they depart therefrom.